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Possible Allelopathic Effects of Reindeer-moss (Cladonia) on Jack Pine and White Spruce

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ABSTRACT. Transplants and seedlings of *Pinus banksiana* and *Picea glauca* were grown in acid sandy soil in the greenhouse and mulched with either *Cladonia rangiferina* or *Cladonia alpestris*, both commonly known as reindeer-moss. After 15 weeks ^{32}P as $NaH_2PO_4 \cdot H_2O$ was added to pots containing transplants. Transplants and seedlings were harvested after 17 weeks and dry weight, nutrient content, and ^{32}P content of the transplants were determined. Both lichens significantly reduced growth and ^{32}P accumulation. FOREST SCI. 25:256–260.

ADDITIONAL KEY WORDS. *Pinus banksiana, Picea glauca,* phytotoxins, phosphorus uptake, mineral nutrition, lichen, taiga, forest tundra.

THE YELLOW-GREEN COLOR AND REDUCED GROWTH of coniferous species on "poor" lichen-covered sandy soils is a common sight in the boreal forest. The question often arises as to whether the poor site is due to the lichen ground cover or whether the lichen ground cover is due to the poor site. Although the work reported here does not answer this question, it does add to existing information indicating that the lichens may be more cause than effect.

The ability of certain plants to interfere with the function of mycorrhizae has profound ecological significance in addition to its practical significance in forestry. *Calluna vulgaris* L. has been reported to interfere with the formation of pine and spruce mycorrhizae (Handley 1963). Extracts of the leaves of *Populus tremula* L. and of *Cladonia* L. have been shown to inhibit the growth of mycorrhizal fungi in culture (Olsen and others 1971). Brown and Mikola (1974) observed that the growth of *Pinus silvestris* L. and *Picea abies* L. was inhibited when these trees grew in conjunction with *Cladonia* and other fruticose lichens.

The work reported here was initiated to determine if two species of *Cladonia*, common in the boreal forest, would interfere with the germination and growth of jack pine (*Pinus banksiana* Lamb.) and white spruce (*Picea glauca* (Moench) Voss).

MATERIALS AND METHODS

Seedlings.—Jack pine and white spruce seed were sown in 400 ml pots containing soil collected from a mature jack pine stand. The soil was a medium sand of pH 5.1 with an average organic carbon content of 1.8 percent by weight. Field capacity and wilting point of the soil material were determined using a pressure plate and converted to gravimetric equivalents. The seeds were covered with a mulch of *Cladonia alpestris* (L.) Rabenh., *C. rangiferina* (L.) Web., or commercial peat moss. The lichens were lifted from the field and placed fresh and as

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TABLE 1. Dry weight and nutrient concentration of shoots of 17-week-old jack pine and white spruce seedlings grown with and without Cladonia *lichen mulch. Values within species with the same superscript letter are not significantly different at the 5 percent level.*

Species and mulch treatment	Dry weight	Nutrient concentration				
		N	P	K	Ca	Mg
Pine:	*mg*	*Percent*				
Peat moss	0.53^{a}	2.47^{a}	0.27^{a}	0.76^{a}	0.23^{a}	0.13^{a}
C. alpestris	0.28^{b}	1.87^{b}	0.13^{b}	0.69^{a}	0.19^{a}	0.11^{a}
C. rangiferina	0.31^{b}	1.96^{b}	0.15^{b}	0.73^{a}	0.19^{a}	0.10^{a}
Spruce:						
Peat moss	0.26^{a}	2.34^{a}	0.30^{a}	1.79^{a}	0.18^{a}	0.15^{a}
C. alpestris	0.11^{b}	1.79^{b}	0.11^{b}	1.54^{a}	0.15^{a}	0.11^{a}
C. rangiferina	0.13^{b}	1.83^{b}	0.19^{b}	1.61^{a}	0.16^{a}	0.13^{a}

undisturbed as possible on top of the soil in the pots. Approximately 25 g (dry weight) of lichen or peat moss was applied per pot. For each tree species 10 pots of each mulch treatment were established and placed at random on a greenhouse bench. The pots were watered through the mulch to field capacity twice weekly and were given a 16-hour day by supplementing sunlight with fluorescent lighting. Two weeks after germination the pine were thinned to 10 trees per pot and the spruce to 20 trees per pot. After 17 weeks of growth the plants were harvested and analyzed.

Transplants.—Seedlings of jack pine and white spruce that had been grown for 35 weeks in Paper-Pots containing a mixture of peat and sand were transplanted into 400 ml pots of the same soil used in the seedling experiment. The transplants were paired as to height and fresh weight so that treated and control plants would be as nearly as possible equal at the beginning of the trial. Pots were mulched with lichen or peat moss as in the seedling experiment. For each tree species nine pairs were established for each lichen species, and these pairs were randomly arranged on a greenhouse bench. The transplants were watered to field capacity twice weekly and were given a 16-hour day by supplementing sunlight with fluorescent lighting. At age 50 weeks from seed, the pots were treated with 500 milligrams of $NaH_2{}^{32}PO_4 \cdot H_2O$ which had a specific activity of 50 microcuries per gram. This was injected in solution beneath the mulch that covered each pot. At 52 weeks of age the plants were harvested and analyzed.

Analysis.—At the conclusion of the growing period the apical centimeter of shoot of each transplant was collected for ^{32}P analysis. This tissue was dried for 24 hours at 70°C, and counts per minute per milligram were determined on a scintillation counter.

The seedlings were dried and weighed, and the shoots were ground for nutrient analysis. The remaining portions of the transplants were dried and weighed, and the shoots were ground for nutrient analysis. The roots of both seedlings and transplants were examined for mycorrhizae.

Nitrogen (N) was determined by semi-micro Kjeldahl and phosphorus (P) by the molybdo-vanadate method, potassium (K), calcium (Ca), and magnesium (Mg) were determined by atomic absorption spectrophotometry after wet-ashing the ground plant material.

Results from the seedling experiment were subjected to an analysis of variance;

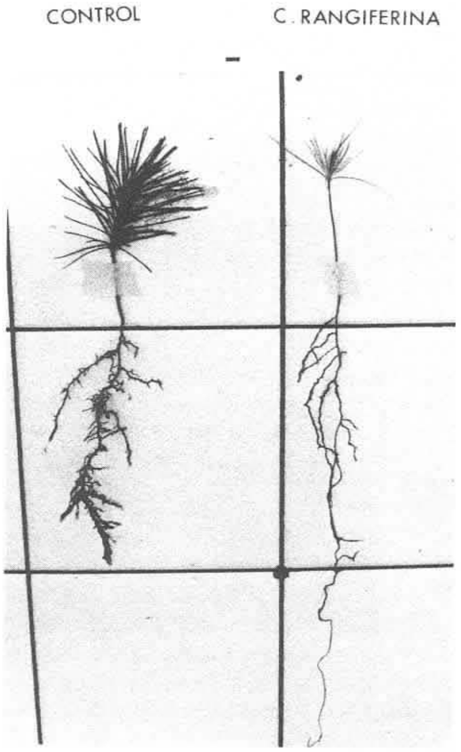

FIGURE 1. Seventeen-week-old jack pine seedlings grown with and without lichen mulch (scale: white squares are 10 × 10 cm).

results from the transplant trial were analyzed using a paired *t*-test. A significance level of 5 percent was used in all cases.

RESULTS

The lichen mulch did not appear to retard germination any more than did the peat mulch; however, both species of lichen did significantly reduce growth and N and P concentration of the jack pine and black spruce seedlings (Table 1).

The concentration of K, Ca, and Mg was not significantly influenced by the lichen mulch treatment. It was observed that the roots of the lichen mulch treated plants were longer but less massive and far less mycorrhizal than those of the control plants (Fig. 1). *C. rangiferina* reduced the root systems more than did *C. alpestris* although the effect of the lichens on total dry weight was not significantly different.

The transplants accumulated only a small portion of their biomass during the treatment period; therefore, the differences between the lichen mulch treated plants and the control plants were not as striking as with the seedlings. However, due partly to the paired seedling design used in this trial, the lichen mulch significantly reduced the total dry weight and N and P concentrations of both pine and spruce (Table 2). As with the seedlings the lichen mulch did not significantly influence the concentration of K, Ca, or Mg in the transplants.

The uptake of ^{32}P served as a more sensitive measure of the lichen's effect on the transplants (Table 3). Both lichen mulch treated pine and spruce showed a significant reduction in their ability to take up and translocate ^{32}P to the growing

TABLE 2. Dry weight and nutrient concentration of shoots of 52-week-old jack pine and white spruce seedlings grown with and without Cladonia *lichen mulch. Values are expressed as percent of peat moss control and are derived from 5 paired observations for each treatment.*

Species and mulch treatment	Dry weight	N	P	K	Ca	Mg
Pine:						
C. alpestris	56*	85*	81*	98	99	99
C. rangiferina	60*	83*	71*	95	99	100
Spruce:						
C. alpestris	58*	77*	62*	99	101	99
C. rangiferina	64*	79*	54*	101	103	102

* Values significantly different from peat moss control at 5 percent level.

tip of the transplant. As would be expected of root systems growing in ^{32}P treated soil, the roots were highly radioactive. The plant tops contained much less ^{32}P label, however, even in the rapidly growing shoot apices.

The root systems of the transplants were largely formed prior to the imposition of the lichen mulch treatment and showed little visible difference from the control.

DISCUSSION

The lichen mulch significantly reduced growth as well as N and P concentrations of both seedlings and transplants of both species. The form of the root system of lichen treated seedlings was altered. The ability of the transplants to take up and translocate ^{32}P was reduced by the lichen mulch. It would seem that this reduction in growth was due to the reduced availability of N and P in the meristematic tissues of the trees which seems to be due to the interference of the lichen in P and possibly N uptake.

The importance of mycorrhizae in P uptake is well established (Stone 1950, Harley 1969). Brown and Mikola (1974) showed that lichen extracts interfered with the growth of mycorrhizal fungi and seemed to reduce the ^{32}P uptake of very young mycorrhizal pine. In the current experiment the root systems of the seedlings were altered under lichen mulch so that fewer mycorrhizae were formed (Fig. 1). The transplant root systems did not seem to have significantly fewer mycorrhizae; however, their inability to take up and translocate ^{32}P could be due to some impairment in the mycorrhizae's function. Unfortunately, the data do not discriminate between uptake and transport, so the effect might be due to

TABLE 3. Mean and standard deviation for ^{32}P content of shoot apices, expressed as percent of control, for 52-week-old jack pine and white spruce seedlings grown with and without Cladonia *lichen mulch.*

Seedling species	Mulch treatment	
	C. alpestris	*C. rangiferina*
Jack pine	62* (9.7)	56* (10.9)
White spruce	48* (15.6)	43* (13.6)

* Values significantly less than control at 5 percent level.

impairment in transport of P rather than uptake. Nonetheless, the lichen has somehow reduced the trees' ability to accumulate P, thereby restricting growth.

The low concentrations of N and normal concentration of K, Ca, and Mg are more difficult to understand. There is ample evidence that mycorrhizae are important in the uptake of K, Ca, and Mg but little evidence that they are important in N uptake (Harley 1969). It is possible that the lichen interferes with the P or N and P uptake processes directly and not with the overall function of the mycorrhizae. It may be simply that mycorrhizae are more important in P uptake than in the uptake of K, Ca, and Mg. N could be low due to poor P nutrition or the process of N uptake may be directly inhibited.

Similar nutrient concentration patterns occur in sugar maple (*Acer saccharum* Marsh.) that are under the influence of allelopathic chemicals from *Solidago* L. This pattern can be corrected by adequate additions of P or N and P to the soil (Fisher and others 1978).

These results demonstrate that *Cladonia* ground covers can reduce the growth of both seedlings and transplants of jack pine and white spruce. The trees are not killed but are merely stunted by the lichen. This stunting is accompanied by poor P and N nutrition that may be related to impairment of root system development. It should be recognized that lichens have considerable ion exchange capacity and may filter out nutrients added to the site by rain or dust fall; however, this mechanism did not operate in these experiments. The evidence from these experiments indicates that the stunted condition of trees growing on "poor" sites with a *Cladonia* ground cover is due at least in part to interference by the lichen.

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